

## TITLE OF THE INVENTION

THREE DIMENSIONAL VOLUMETRIC DISPLAY INPUT AND OUTPUT CONFIGURATIONS

## CROSS-REFERENCE TO RELATED APPLICATION(S)

**[0001]** This application is related to, is a continuation of and claims priority to U.S. application entitled Three Dimensional Volumetric Display Input and Output Configurations, having serial number 10/183,970, by Kurtenbach et al., filed June 28, 2002 (allowed), which claims priority to U.S. provisional application entitled User Interfaces For Volumetric Displays, having serial number 60/350,952 (S&H Docket 1252.1054P), by Kurtenbach et al, filed January 25, 2002. This application is also related to U.S. application entitled Volume Management System For Volumetric Displays, having serial number 10/183,966 (S&H Docket 1252.1065), by Kurtenbach et al, filed June 28, 2002, to U.S. application entitled Widgets Displayed And Operable On A Surface Of A Volumetric Display Enclosure, having serial number 10/183,945 (S&H Docket 1252.1066) by Fitzmaurice et al, filed June 28, 2002, to U.S. application entitled Graphical User Interface Widgets Viewable And Readable From Multiple Viewpoints In A Volumetric Display, having serial number 10/183,968 (S&H Docket 1252.1067), by Fitzmaurice et al, filed June 28, 2002, to U.S. application entitled A System For Physical Rotation of Volumetric Display Enclosures To Facilitate Viewing, having serial number 10/183,765 (S&H Docket 1252.1068), by Balakrishnan et al, filed June 28, 2002, and to U.S. application entitled Techniques For Pointing To Locations Within A Volumetric Display, having serial number 10/183,944 (S&H Docket 1252.1069), by Balakrishnan et al, filed June 28, 2002, and all of which are incorporated by reference herein.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

**[0002]** The present invention is directed to input and output configurations for three-dimensional volumetric displays and, more particularly, to input configurations that allow the content of a three-dimensional volumetric display output configuration to be affected by actions by a user operating within an input configuration.

### 2. Description of the Related Art

**[0003]** A class of three-dimensional (3D) displays, called volumetric displays, is currently undergoing rapid advancement. The types of displays in this class include holographic displays,

swept volume displays and static volume displays. Volumetric displays allow for three-dimensional (3D) graphical scenes to be displayed within a true 3D volume. Such displays can take many shapes including cylinders, globes, domes, cubes, an arbitrary shape, etc. with a dome being a typical shape. Because the technology of these displays is undergoing rapid development those of skill in the art are concentrating on the engineering of the display itself. As a result, the man-machine interface to or input/output configurations with which people interface with these types of displays is receiving scant attention.

**[0004]** While the volumetric displays allow a user to view different parts of a true 3D scene, the act of viewing the different parts typically requires that the user physically move around (or over) the display or that the display be moved or rotated in front of the user. As the display moves relative to the user, graphical objects may also move relative to the user. When the display is relatively stationary or when it is relatively moving, the user may need to interact with the display. As a result, what the user needs is an effective mechanism for interacting with the display.

#### SUMMARY OF THE INVENTION

**[0005]** It is an aspect of the present invention to provide effective mechanisms for a user to interact with content of the three-dimensional volumetric display.

**[0006]** It is also an aspect of the present invention to provide input and output configurations for a three-dimensional volumetric display.

**[0007]** It is another aspect of the present invention to provide dome, cubical and cylindrical output configurations.

**[0008]** It is also an aspect of the present invention to provide input configurations that allow a 3D volumetric input space to be mapped to the 3D volumetric display, a planar 2D input space to be mapped to the 3D volumetric display, a planar 2D input space to be mapped to a planar 2D space within the 3D volumetric display, and a non-planar 2D input space to be mapped to the 3D volumetric display.

**[0009]** The above aspects can be attained by a system that allows a number of 3D volumetric display configurations, such as dome, cubical and cylindrical volumetric display enclosures, to interact with a number of different input configurations, for example, a three-dimensional position sensing system, a planar position sensing system and a non-planar position sensing system. The user interacts with the input configurations, such as by moving a

stylus on a sensing grid formed on an enclosure surface. This interaction affects the content of the volumetric display, for example, by moving a cursor within the 3D display space of the volumetric display.

**[0010]** These together with other aspects and advantages which will be subsequently apparent, reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** Figure 1 shows a volumetric display.

**[0012]** Figures 2, 3 and 4 depict a 3D to 3D system configurations.

**[0013]** Figures 5, 6 and 7 depict 2D to 3D configurations.

**[0014]** Figure 8 shows a non-planar to 3D configuration.

**[0015]** Figures 9, 10, 11, 12, 13 and 14 show configurations with physical intermediaries.

**[0016]** Figure 15 depicts components of the system

**[0017]** Figures 16A, 16B, 16C and 16D illustrate digitizer embodiments.

**[0018]** Figures 17 illustrates components of a digitizer.

**[0019]** Figures 18A, 18B and 18C show details of a dome shaped digitizer.

**[0020]** Figure 19 depicts the operations of the system.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0021]** Volumetric displays allow a user to have a true three-dimensional (3D) view of a scene 12 and are typically provided in the form of a dome 14, as depicted in figure 1. The user 16, as can be surmised from figure 1, can move about the dome 14 to view different parts of the scene 12. From a particular arbitrary viewpoint or position, a user may want to interact with the scene or content within the volumetric display.

**[0022]** There are a number of different solutions to this problem. These solutions involve creating input/output configurations for the volumetric display that define a spatial correspondence between an input space and an output space. The configurations also define a dynamically updatable spatial correspondence of the input and output spaces with the user.

**[0023]** In a first solution, a 3D volumetric input space is mapped to a 3D volumetric display space. In one configuration, as depicted in figure 2, the user's hand 30 is tracked via a glove or a set of cameras in a volume 32 directly below the display volume 34. A virtual representation of the hand 36, or some other type of position indicator, such as a cursor, is superimposed into the 3D output volumetric display 34. In a second configuration, as depicted in figure 3, the 3D display 50 is surrounded by a 3D input space 52, created by a 3D volume input system, such as the Flock of Birds system from Ascension Technology Corporation. In this configuration, the user's hand 54, including a position indicator/sensor, is mapped to a cursor 56 or some other position indicator representation, such as a virtual hand, within the display 50. The position sensor also produces a vector that indicates which direction the sensor is pointing. The vector can be used to create a cursor in the enclosure at a fixed position along the vector. Rather than using the vector produced by the position sensor, the system infers an input vector based on the position of the input device and the center of the display. This spatial relationship or correspondence between the input space, output space and user position is dynamically updated as the user moves about the display. That is, the input/output space is automatically compensated/reconfigured. Another configuration is to use half-silvered mirrors 70 (see figure 4) to combine the volumetric image 72 with the user's view of their hands in a hand movement volume. This way, the user sees their hands operating within the display. Another alternative is to use a camera to capture the users hands in the input space and superimpose them onto the volumetric display space. Another alternative is an augmented-reality system where the user has a see-through, head mounted display (2D) which is being tracked. As the user moves the position and orientation of their head, graphics are presented on the LCD display and are aligned with real-world objects.

**[0024]** Another solution is to map a planer 2D input space into a 3D output space. This is particularly useful in controlling some subset of the 3D volumetric display space. For example, a standard 2D digitizing tablet or digitizer 90 (see figure 5) or a regular mouse can be mapped to control aspects of the 3D scene, such as moving 3D objects along two dimensions.

**[0025]** A further solution is to map a planar 2D input space to a planar 2D space within the 3D output space of the display, as depicted in figure 6. In this situation, the system maps the input space of a digitizing tablet 110 and the tilt/orientation of the tablet as sensed by a tilt/orientation sensor 112 to a corresponding planar space 114 in the display 116. The angle of the plane 114 is responsive to the sensor 112. If the display enclosure 130 has planar surfaces

(e.g., a cubic enclosure), the enclosure surface is used as the planar input device, as depicted in figure 7. It is also possible to use a transparent digitizer superimposed over an LCD display.

**[0026]** Still another solution is to map a non-planar 2D input space to a 3D output space. In this solution, as depicted in figure 8, the system uses the display enclosure 140 as the input space (i.e., the enclosure is a transparent digitizing input surface). In this embodiment, the position 142 touched by the user or indicated by a pointing device, such as a stylus or surface fitting curved mouse, is mapped to a position in the display. This is a direct and compelling way to interact with these displays.

**[0027]** In addition to direct manipulation using the hands, the solutions described herein also provide physical intermediaries between the hands and the input space as described below.

**[0028]** Another solution when the user desires to interact directly with the enclosure surface, is to deform the surface 160 of a conventional deformable membrane surface that detects multiple pressure points and finger pinches 162, as depicted in figure 9. In this situation, the surface to display mapping discussed above is performed.

**[0029]** Instead of using the hands directly on the enclosure surface, the system has a surface that detects and tracks a variety of input devices. A digital stylus 180, as shown in figure 10, where a point and an orientation can be input or a Rockin'Mouse shaped device 190, as shown in figure 11 (see U.S. Patent 6,115,028) also allowing a point and an orientation to be input are used. A surface fitting wireless mouse, such as a curved (concave) bottom mouse, can be used with a curved surface output configuration. This type of mouse can also be park-able using electrostatic, magnetic or some other sticky method of removably adhering the mouse to the display surface. Using a mouse has the advantage of buttons and form factors with which people are familiar. In this situation, the surface to display mapping discussed above is performed.

**[0030]** The physical intermediaries also do not have to be on the enclosure itself as described below.

**[0031]** In an embodiment input devices 200, such as buttons, keyboards, sliders, touch-pads, mice and space-ball type devices, etc., are mounted along the perimeter of the display (see figure 12). In this embodiment, the input devices such as buttons for up, down, forward, backward, left and right motions, allowing multiple degrees of freedom, are used to control the position of a cursor like such buttons control the position of a cursor in a 2D system. The input

devices 210, 212, 214 may need to be "repeated" (i.e., have more than one of each along the perimeter) to allow for simultaneous use by many users, or for use from any position the user may be standing/sitting at as shown in figure 13. Rather than having multiple input devices positioned around the display as depicted in figure 13, the mounting platform 220 that houses these devices could be made moveable (rotatable) around the display, as depicted in figure 14, so that users can easily bring the required device within reach by simply moving the platform. These devices typically communicate wirelessly by radio or infrared signals. The position of the movable device also provides information about the user's position or viewpoint.

**[0032]** The present invention is typically embodied in a system as depicted in figure 15 where physical interface elements 230, such as a rotary dome position encoder, infrared user position detectors, a keyboard, touch sensitive dome enclosure surface, mouse, beam pointer, beam pointer with thumbwheel, stylus and digitizer pad or stylus and stylus sensitive dome enclosure surface, stylus with pressure sensor, flock-of-birds, etc. are coupled to a computer 232, such as a server class machine. The computer 232 uses a graphical creation process, such as the animation package MAYA available from Alias|Wavefront, Inc., to create three-dimensional (3D) scene elements. This process, using position inputs from the input configurations as discussed herein, also creates the virtual interface elements, such as a virtual hand, a 3D point cursor, a 3D volume cursor, a pointing beam, a bead, etc. The display output, including the scene and interface elements, is provided to a volumetric display apparatus configuration 234, such as one that will produce a 3D holographic display and discussed herein.

**[0033]** The configurations that include a transparent digitizer or touch sensitive surface have a number of different shapes as depicted in figures 16A - 16D. In one embodiment a dome shaped enclosure 250 has a dome shaped digitizing tablet as depicted in figure 16A. In another embodiment the dome shaped enclosure 256 (see figure 16B) is used with a rectangular or cylindrical shaped digitizing tablet 258. In a further embodiment, as shown in figure 16C, a cylindrical or cubical enclosure 260 is used with cylindrical or cubical digitizer surface. In a different embodiment the enclosure 264 is dome shaped (or cubical or cylindrical) and the digitizing surface 266 is planar as depicted in figure 16D.

**[0034]** A digitizer 280 (see figure 17), such as described in U.S. Patent 5,854,449 incorporated by reference herein, determines a position of a stylus or pointer 282 relative to a surface 284, such as a transparent dome surface, having a checker board type closely spaced positional grid 286 thereon when seen from above. A processor 288 determines the coarse

position of the pointer relative to the grid by sampling the grid lines through a set of multiplexers 290 and 292. An error correction system 294 generates and outputs a true position of the pointer 282 relative to the surface 284 to a computer system 232 (see figure 15). The pointer 282 typically includes an electromagnetic transducer for inducing a signal in the positional grid 286 and the processor 288 is coupled to the positional grid 286 for sensing the signal and generating the coarse position of the pointer 282. The transducers also allow the determination of a vector from grid signals that indicates in which direction the pointer 282 is pointing. Touch sensitive input surfaces operate in a similar fashion.

**[0035]** The positional grid 286 can be applied to a surface of an enclosure, such as a dome shaped enclosure 310, as depicted in figures 18A and 18B. Figures 18A and 18B (an exploded view) show a section 312 of the dome surface including an inner substrate 314 and outer substrate 316 between which is sandwiched the grid 318. The substrates comprise transparent materials, such as glass or plastic.

**[0036]** In using these input and output configurations the computer system 232 (see figure 15) performs a number of operations as depicted in figure 19. The operations include obtaining 330 the coordinate systems of the input device and the volumetric display. The range of the coordinate systems is also obtained so that out-of-space conditions can be determined. Next, the system samples 332 positional outputs of the input device, such as the digitizer, mouse, flock-of-birds, etc., to obtain the location of the users input. This information can also include information about where the user is pointing. This position (and orientation if desired) is mapped 334 into a 3D position within the volumetric display using the coordinate system (and the orientation vector, if needed). The cursor or other position indicating representation, such as a virtual hand, is drawn 336 at the mapped position with the volumetric display. The mapping may involve determining a position on the surface that is being touched by a digitizing stylus, projecting a ray into the enclosure from the touch position where the ray is oriented by the pointing vector of the input stylus and positioning the cursor at a variable or fixed position along the ray. Another mapping causes relative motion of a 3D input device such as a glove to be imparted to a cursor when a motion function is activated. Other mappings as discussed in the related applications are possible.

**[0037]** The operations described with respect to figure 19, when a digitizing enclosure surface is the input configuration, allow the user to interact with a surface of a three-dimensional (3D) volumetric display and affect the 3D content of the display responsive to the interaction.

The interaction involves the user manipulating the stylus in a sensing region of the digitizing grid, the mapping of the stylus position to a 3D display position and the creation of a cursor at a 3D display position. The cursor, in one of a number of different possibilities, is created at a distance offset from a tip of the stylus along a pointing vector of the stylus. The cursor can be used to perform typical functions such as selecting, painting, dragging/dropping, etc.

**[0038]** The present invention has been described with respect to input configurations where commands are input through position sensing type devices, such as a mouse, a pointer, touch sensitive surface, etc. It is also possible to use other types of input configurations, such as non-spatial configurations. One non-spatial input space or configuration is a conventional voice or speech recognition system. In this configuration a voice command, such as "down" is recognized and the selected object or volume is moved accordingly. In this case down. The object is moved down in the display space at a constant slow rate until it reaches the bottom or until another command, such as "stop" is input and recognized. For user centric commands, such as "move closer", a user position sensing system inputs the user position, the position is used to determine the relative position of the active object with respect to the user or the vector pointing from user to the object. This vector is used to determine a direction for object movement. To move closer the object is moved along the vector toward the user by moving in a negative direction. Again the motion would continue until a blocking object is encountered or another command is recognized.

**[0039]** Another non-spatial input configuration uses non-speech sounds, such as tones from a conventional multifrequency tone generator. Each multifrequency combination corresponds to a command and a conventional tone recognition system is used to convert the sounds to commands.

**[0040]** The input space or configuration could also use conventional eye-tracking-head-tracking technologies alone or in combination with other input configurations.

**[0041]** The many features and advantages of the invention are apparent from the detailed specification and, thus, it is intended by the appended claims to cover all such features and advantages of the invention that fall within the true spirit and scope of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.